FRESHWATER TURTLE POPULATIONS IN THE BURNETT RIVER

MARK HAMANN, CHLOE S. SCHÄUBLE, SAMANTHA P. EMERICK,
DUNCAN J. LIMPUS AND COLIN J. LIMPUS

Hamann, M., Schäuble, C.S., Emerick, S.P., Limpus, D.J. & Limpus, C.J. 2008 04 30. Freshwater turtle populations in the Burnett River. *Memoirs of the Queensland Museum* **52**(2): 221–232. Brisbane. ISSN 0079-8835.

A study was conducted on freshwater turtle populations residing in a section of the Burnett River to be flooded by the Paradise Dam. Four species were found with *Emydura macquarii krefftii* being the most common. The population of this species was bias towards adult sized turtles, with poor recruitment or low survivorship of hatchlings. The size at which 50% of the population had reached adulthood was 18.2cm and 20.6cm for males and females respectively. *Elseya albagula* and *Wollumbinia latisternum* occurred at very low densities. Both these species also showed a population bias towards adult sized turtles, despite annual breeding by adults. *Chelodina expansa* was rare with only four individuals caught. Morphometric and reproductive characteristics for the three most common species will enable an assessment of the impact of the Paradise Dam on turtle populations. ❒ *Freshwater, riverine, turtles, impoundments, ecology, reproduction, growth.*

Mark Hamann, School of Earth and Environmental Sciences, James Cook University, Townsville, Qld 4811 & Queensland Parks and Wildlife Service, PO Box 1735, Bundaberg, Qld 4670; Chloe Schäuble, Burdekin Dry Tropics NRM, PO Box 1466, Townsville, 4810 & Queensland Parks and Wildlife Service, PO Box 1735, Bundaberg, 4670; Samantha P. Emerick, Queensland Parks and Wildlife Service, PO Box 1735, Bundaberg, 4670; Duncan J. Limpus & Colin J. Limpus, Queensland Parks and Wildlife Service, P.O Box 15155, City East (Brisbane), 4002. Corresponding author: Dr Mark Hamann, (email: mark.hamann@jcu.edu.au); 9 August 2007

Many species of riverine turtles are declining worldwide, and freshwater turtles are impacted by stream impoundments in a similar way to fishes and invertebrates (Bodie, 2001). The Burnett River in Queensland, Australia, is highly modified. The latest change has been the completion of the large Paradise Dam in 2005, however numerous other water infrastructures exist along the river's length. The potential threat from multiple impoundments to the system's five freshwater turtle species has four facets: habitat loss, habitat fragmentation, aquatic health and condition impacts, and barriers to dispersal and/or migration (Hamann et al., 2004).

In a study to investigate the impact of dams and weirs on freshwater turtle populations in Queensland's Fitzroy-Burnett-Mary Catchments, Tucker (1999) concluded that the loss of edible fruit from riparian vegetation, the loss of suitable nesting banks, and the loss of freely flowing sections of rivers, are likely to influence the diversity of species and population characteristics of freshwater turtle species in areas that become impounded. Studies within the Burnett River Catchment also show that impoundment structures not only frequently act as barriers to turtle movements, but can also cause high rates of injury and mortality to turtles washed over walls, or living in downstream water release areas (Hamann et al., 2004). Such impacts need to be monitored, and effectively managed, as they can affect population function and ultimately the survival of some species.

Effective management of natural turtle populations requires suitable baseline data for key population demographic parameters and morphological characteristics. These data can be used to identify populations currently under stress, those that have become stressed, and those that are recovering from stress (e.g. Gibbons et al., 2001, Romero & Wikelski, 2001, Fonnesbeck & Dodd, 2003). Limpus et al. (2002) conducted a 'pre-construction' baseline study of freshwater turtle populations in the area of the Burnett River to be flooded by the Walla (now known as Ned Churchward) Weir. Data from their study has been important in post construction monitoring at that weir. The present study provides such pre-construction baseline information on freshwater turtles at sites upstream and downstream of the Paradise Dam at AMTD 131.2 on the Burnett River, SE Queensland. Hopefully it will be similarly useful for monitoring turtle abundance, diversity, health, and population demography, as the impacts of this new, and much larger, impoundment take effect.

MATERIALS AND METHODS

The undescribed *Elseya* species in Limpus et al. (2002) and Hamann et al. (2004) has been described as *Elseya albagula* Thomson, Georges and Limpus, 2006. Our study builds on the data for *E. albagula* presented by Hamann et al. (2004) using increased sample sizes, and information on an additional three turtle species.

STUDY SITE

Freshwater turtles were caught at six sites in the section of the Burnett River between AMTD 130 and AMTD 175. These sites included one site (Campbell's Property 25.3374°S, 151.9267°E) downstream of the Paradise Dam, the Paradise Dam site (25.3514°S, 151.9181°E), and four sites upstream of the Paradise Dam site but still within the area to be flooded by the impoundment (Paradise 25.3551°S, 151.8953°E, Goodnight Scrub 25.3582°S, 151.8785°E, Mingo Crossing 25.3984°S, 151.7773°E, and Gahans Road Crossing 25.4190°S, 151.6889°E). The number of days spent catching turtles at each site was not equal and ranged from two days at Mingo Crossing up to 28 days at Goodnight Scrub. While most turtles were sampled between 2002 and 2004, we have included 62 turtles (59 *Emydura macquarii krefftii* (Gray 1871) and 3 *Wollumbinia latisternum* (Gray 1867)) that were caught at Goodnight Scrub during 1997 or 1999 as part of a previous Queensland Parks and Wildlife (QPWS) study (Tucker, 1999). Most of the field work at all sites was conducted prior to the alteration of the river in June 2004, and the associated start of construction on the Paradise Dam. Eight days of field work occurred during the construction phase; two days at a 50m long shallow section of river (c.a. 0.5 to 1m deep) that was pumped dry during the construction process to allow the footings of the dam wall to be constructed; and six days catching turtles in the pools immediately up and downstream of the site of the dam wall.

The substrate within each section of the river was similar and comprised a mixture of sand and volcanic rocky substrate (Benjamin, 1995; Van Manen, 1999). At sampling locations water depths were generally less than three metres and the river consisted of pool-riffle-pool formations. *Callistemon* spp. grew along most banks and their branches often draped into the water providing in-stream structure. With the exception of the river bank associated with Goodnight Scrub National Park, riparian vegetation was limited in width (usually < 50m).

TURTLE CAPTURE AND DATA COLLECTION

Studies in other areas of the Burnett River Catchment have indicated that populations of freshwater turtles showed a low frequency of younger (immature) age classes. We therefore used a variety of capture methods over a range of microhabitats, and at different times of the year, in an effort to sample turtles of all age classes. Turtles were captured by snorkelling, trapping, dip-netting, seine netting or searching through the mud or shallow water (for method descriptions see Tucker, 1999; Limpus et al., 2002; and Hamann et al., 2004). Snorkel captures involved locating turtles visually while swimming underwater along the sides and bottom of the river and capturing them by hand. Three trap designs were used: submerged modified collapsible traps with wide funnel openings; floating modified collapsible traps with internal floats; and the cathedral trap version of the modified submerged collapsible traps (see Hamann et al., 2004 for description). Deployed cathedral style traps were positioned so that the top of the upper compartment was out of the water allowing turtles to surface and breathe. Traps were baited with a variety of fruit and/or meat products. Submerged traps were checked every 1–2 hours depending on water temperature. Cathedral style traps and floating traps were checked at least once every 24 hours. Dip-netting and hand captures were generally made while spotlighting at night on foot or from a boat. Use of seine nets was limited due to the rocky boulder substrate in this section of the river. Seine net mesh sizes ranged from 5.5cm to 15.2cm and nets were used singly or in combination. In the section of river that was pumped dry, once all the water was removed we were able to systematically work our way through the area searching by hand for any turtles that were under rocks or buried in the mud.

Turtles were tagged using the standard methods described by Limpus et al. (2002) and Hamann et al. (2004). Each turtle was tagged with a self-locking, self-piercing monel tag in the webbing of a hind foot and/or coded with one or more notches in the marginal scutes. In addition, during July and August 2004 all turtles over 15cm straight carapace length (SCL) 39 *E. m. krefftii* and 3 *W. latisternum*) caught at the Paradise Dam site were tagged with passive integrated transponder tags (PIT) tags (23mm Eco-line RI-TRP-REHP) that were compliant with the anticipated inclusion of an automated tags PIT tag scanner in the fishway of the Paradise Dam. Morphological measurements were taken with vernier callipers as described in Limpus et al. (2002) and Hamann et al. (2004). Weight was measured either by electronic balance (± 0.05–1.0 g) or, for turtles over 3kg, a spring balance (± 50 g). Scute counts were conducted on most turtles when they were caught for the first time. Nomenclature of scutes follows Pritchard & Trebbau (1984) except that 'supracaudal' scutes are included in the marginal scute count. Plastron curvature was determined by placing a straight edge along the plastron and categorising plastron shape in relation to the midline axis of the turtle, as convex, concave, or flat. Gender of turtles was assessed by three ways: first, by laparoscope examination; second by using morphometric measurements (the relationship between tail size and carapace length); and lastly some females carrying oviducal eggs were identified as adults by palpation of eggs through the inguinal pocket (following methods of Limpus et al. (2002)). Laparoscopy allows the gonads of turtles to be examined visually to determine gender, sexual maturity, and breeding status (following the methods of Limpus et al. (2002) and Limpus & Limpus (2003)).

Growth layers on the carapace and/or plastron scutes were counted to record the minimum age of individual turtles where the entire growth sequence from the hatchling scute or the first-year growth layer remained visible (Hamann et al., 2004). For example, if a turtle had six growth layers separated by five rings, it was deemed to be in its sixth year. Only turtles for which the hatchling scute was visible have been included in this analysis. Each growth layer (annulus) on a scute is assumed to represent a year of growth.

The size at which 50% of the turtles are sexually mature (AS_{50}) was determined following the methods of Limpus et al. (2002). In short, the proportion of adult turtles in 1cm size classes was analysed using logistic functions. The goodness of fit was determined by the residual variance and log likelihood functions.

During the 2003 and 2004 breeding seasons for *E. albagula* (April to September, Hamann et al., 2004) the Gahan's Road, Goodnight Scrub, Paradise Dam and Campbell's property sites were searched to locate turtle nests. Determination of species was based on egg shell measurements and comparison with the key presented by Hamann et al. (2004). Nest searches were not conducted to identify nesting habitat of the spring–summer laying species *W. latisternum* and *E. m. krefftii.*

Unless otherwise stated, means are presented with standard deviations. Statistical significance was accepted at $p < 0.05$. Data that failed tests of normality were log transformed. Statistics

TABLE 1. Frequency of captures by method for freshwater turtles in the Paradise Dam area of the Burnett River.

Method	*Emydura m. krefftii*	*Elseya albagula*	*Wollumbinia latisternum*	*Chelodina expansa*
Snorkelling	131	16	2	2
Seine netting	2	0	0	0
Dip netting	14	0	0	0
Trapping	332	1	30	2
Night spotlighting	4	2	0	0
Drained pool search	4	0	1	0
Method not recorded	47	2	2	0
Killed by construction activities associated with the dam	0	0	1	0
Total	**534**	**21**	**36**	**4**

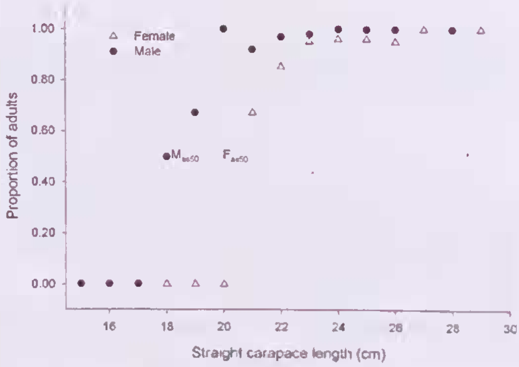

FIG. 1. Calculation of AS_{50} values for adult male and female *Emydura macquarii krefftii* from the Paradise Dam Area of the Burnett River (female logistic equation y = 0.9601/1+(SCL/20.81)^-90.50) and male logistic equation y = 0.987/1+(SCL/18.232)^-30.206). M and F correspond to the calculated AS_{50} for each sex.

were conducted using S Plus software (Krause & Olson 2002).

RESULTS

Four species of freshwater turtles were caught in this study. *Emydura macquarii krefftii* (Gray 1871) comprised 89.8% of captures; *Emydura albagula* Thomson, Georges and Limpus, 2006, 3.5%; *Wollumbinia latisternum* (Gray 1867), 6.0%; and *Chelodina expansa* (Gray 1857), 0.6%.

Emydura macquarii krefftii (Gray 1871)

POPULATION CHARACTERISTICS. *E .m. krefftii* was the most common turtle in the river. It was captured at all study sites, and by using each of the study methods. Most individuals were caught by either snorkelling or trapping (Table 1). Because the relationship between tail length and SCL is not a precise measure of sex or maturity, our analyses are based on animals for which sex and maturity were confirmed by laparoscopic examination or by the presence of oviducal eggs by palpation. Based on the data for which maturity was confirmed there is a wide range of sizes over which the transition from 100% immature to 100% mature occurred, and the range of sizes over which this transition occurred differed between sexes (Fig. 1). The relationship between size and maturity which provided the best estimate of the size at which 50% of the turtles were adult (± 95% confidence limits) was a logistic function that differed for each sex. For females: y = 0.9601/1+(SCL/20.81)^-90.50 and r^2 = 0.996; F = 1642.43; $P < 0.001$; F = 1670.36; $P < 0.001$. For males: y = 0.987/1+(SCL/18.232)^-30.206 and r^2 = 0.993; F = 1642.43; $P < 0.001$). In females the range of SCLs for 100% immature and 100% mature groups was 20–27cm, and the AS_{50} was 20.81 ± 0.04cm (Fig. 1). In male turtles the range of SCLs from 100% immature and 100% mature animals was 17–24cm, and the AS_{50} was 18.23 ± 0.04cm (Fig. 1).

The size class distribution by sex of captured *E. m. krefftii* shows a low frequency of individuals among the smaller age classes (Fig. 2). Of the 539 *E. m. krefftii* caught over the six sites within the study area there were: 191 confirmed as adults (74 males and 117 females); 222 that were either above the minimum breeding size but not assessed for maturity, and/or did not have their tail lengths recorded; 9 pubescent immature (6 females and 3 males); 21 sexed prepubescent immature (16 females and 5 males); and 96 that were not assessed for gender or maturity. The population sex ratio included the 191 individuals that had sex determined through laparoscopy and 79 females and 109 males for which sex, but not maturity, could be determined using tail length. Turtles with SCL < 27cm and tail lengths >5cm were classed as male and those with SCL> 21cm and tail lengths < 5cm were classed as female (Fig 3.). The resulting sex ratio (183 males and 196 females) is not significantly different to 1:1 F:M (X^2 = 0.90; $P > 0.05$).

Adult females were larger than adult males in all aspects except tail measurements (Table 2). A significant linear relationship occurred between log weight and log SCL for; all turtles (combined sexes and age classes) (r^2 = 0.96; df = 1,216; F = 2554.23; $P < 0.001$), females (combined age classes) (r^2 = 0.96; df = 1,135; F = 4194.91; $P < 0.001$) and male (combined age classes) (r^2 = 0.86; df = 1,80; F = 499.26; $P < 0.001$). However, this log weight and log SCL relationship was significantly different between the sexes (ANCOVA; F = 59.32; df = 2, 216; $P < 0.01$). In addition, the log weight and log SCL relationships for turtles in our study were not significantly different to the relationship for turtles caught in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002; ANCOVA F = 0.37; df = 1, 812; P = 0.54).

Adult female turtles caught in our study were similar with regard to both weight and length to those caught in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002; SCL = t test = 0.93; $P > 0.05$ and weight t test = 0.20; $P > 0.05$). However adult males from our study were both longer and heavier than those reported by Limpus et al. (2002) (SCL = t test = 4.30; $P < 0.05$ and weight = t test = 4.90; $P < 0.05$).

REPRODUCTIVE BIOLOGY. Of the 117 adult female *E. m. krefftii* examined with a laparoscope, only four (3.54%) were preparing to breed, or breeding for the first time. The average SCL of these recruits to the adult population was 23.40 ± 1.13cm (range 22.26 to 24.96 cm).

With regard to seasonal patterns, all 27 females examined in May (8), July (5), or August (14), had bred in the previous season and were in vitellogenesis for the next season. During September the majority of females examined (21 of 30) were carrying oviducal eggs, and laparoscopic examination of the remainder indicated that they were in late vitellogenesis with approximately mature ovarian follicles in preparation for their first clutch for the season. Similarly in October most turtles examined were carrying oviducal eggs (22 of 36). A laparoscopic examination of five of this October group revealed one to be carrying her first clutch for the season, while two were carrying their second clutch for the season. Seven other females examined in October that were not carrying oviducal eggs were in late vitellogenesis and were yet to ovulate their first clutch for the season. During November four of the 14 turtles examined were carrying oviducal eggs, one was not breeding for that season and nine had ovulated at least one clutch and were carrying sufficient mature follicles for an additional clutch of eggs for the season. In December, all six of the females examined had laid at least one clutch for the season, and each had sufficient follicles to lay an additional clutch. In January and February all of the 18 turtles examined (10 in January and 8 in February) had completed egg laying for the season, and 17 had not yet begun vitellogenesis for the next season. Additionally, all 19 turtles caught outside of the breeding season (July and August) had ovarian scars consistent with having bred in previous season and had ovaries containing large developing follicles. Hence these 19 turtles were all breeding in two consecutive seasons. Thus *E. m. krefftii* in this section of the Burnett River Catchment breed seasonally, with the nesting season occurring between late spring through until mid summer. While our laparoscope data indicate that most turtles are

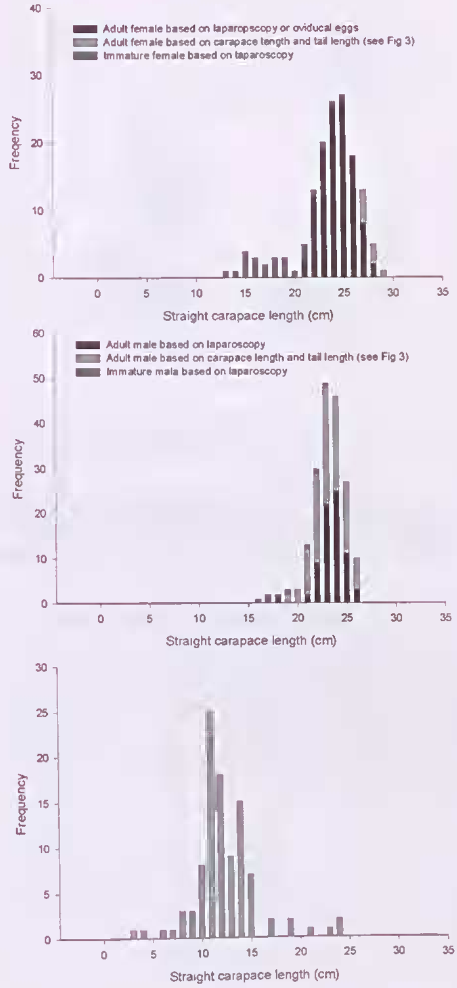

FIG. 2. Distribution of maturity ratio by 1cm increments of size for *Emydura macquarii krefftii* A, female, B, male and C, turtles that were not assessed for sex and maturity from the Paradise Dam area of the Burnett River.

capable of laying more than one clutch of eggs in a season, neither the total number of clutches laid per female or the number of eggs per clutch was determined in our study. 116 of the 117 adult females examined bred in the current breeding season. Approximately 100% of adult females bred in successive seasons.

During this study 74 adult male *E. m. krefftii* (plus one caught and examined twice at different times of the year) were examined using a laparoscope to identify their breeding status. 59 of the 60 male turtles examined between July and November (5 in July, 20 in August, 9 in September, 15 in October, 11 in November) had a large

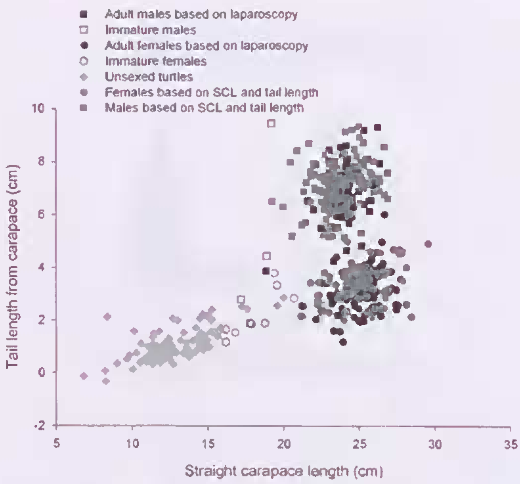

FIG. 3. Relationship between tail length from carapace and straight carapace length for *Emydura macquarii krefftii* in the Paradise Dam area of the Burnett River.

pendulous epididymus with a distended white duct indicating that they were in spermatogenesis for the up-coming breeding season. During December only three out of five turtles examined were in active spermatogenesis, and in January all 10 turtles examined had a pendulous epididymus with no distended white duct and were thus in a quiescent state. Males are seasonally spermatogenic. The male spermatogenic cycle is in synchrony with the female reproductive cycle. Based on mid year samples (July to October) 97% of adult males were in preparation for breeding for the year.

SITE FIDELITY. There were 30 short term (< six months) and 21 long term (> six months) recaptures of *E. m. krefftii* prior to the closing of the wall. The short term recaptures comprised 6 adult males, 12 adult females, 9 unsexed immature and one each of male and female pre-pubescent immature and a female pubescent immature. These turtles were recaptured between 11 and 92 days after their initial capture, and recaptures of all of these individuals occurred within the same pool as their original capture. Among the long term recaptures 12 were adult females, five were unsexed immature, three were female pre-pubescent immature and one was an adult male. These turtles were recaptured between 238 and 1787 days after their initial capture. While 20 of the long term recaptured animals were caught in the same pool as their initial capture, an adult female (tag 24311) was initially captured at Paradise and then recaptured four kilometres downstream at the Paradise Dam site.

GROWTH. Individual growth rates were analysed for the turtles recaptured over periods greater than six months. The average length of time between captures for the 12 adult females was 1135 ± 584 days. Over this period the average change in SCL was 0.48 ± 0.49cm (range 0.02 to 1.58cm). The average length of time between captures for the immature turtles was 343 ± 108 days. Over this period the average change in SCL was 1.60 ± 1.61cm (range -0.12 to 4.02cm). Only two unsexed immature turtles had recognisable hatchling scale and carapace growth layers; these turtles were within their fourth (SCL = 13.58cm) and sixth (SCL = 13.94cm) year of growth.

TABLE 2. Measurements of adult *Emydura macquarii krefftii* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	25.17	1.69	21.20–29.55	113	23.98	1.22	18.82–26.89	73
Straight carapace width (cm)	18.98	1.26	15.38–22.17	88	17.68	0.79	14.60–20.04	48
Plastron length (cm)	20.62	1.29	17.40–23.98	101	19.41	0.80	15.32–24.40	48
Plastron width (cm)	9.59	0.65	8.17–10.72	85	8.78	0.45	7.10–10.14	48
Head length (cm)	5.69	0.52	4.51–6.92	77	5.18	0.45	3.58–6.57	26
Head width (cm	4.04	0.40	3.31–4.90	64	3.55	0.28	1.94–4.26	26
Tail length from carapace (cm)	3.17	0.81	1.17–4.97	103	6.90	1.05	3.87–9.33	73
Tail length from plastron (cm)	7.22	1.05	5.54–9.30	61	11.10	1.02	8.38–13.89	26
Tail length from vent (cm)	3.84	0.71	2.21–5.56	61	4.96	0.95	3.40–8.38	26
Weight (kg)	1.97	0.39	1.08–3.02	113	1.54	0.23	0.70–2.35	72

SCUTE COUNTS. Scute counts were conducted on 408 individuals. While most turtles had a scute count of one nuchal scute, 4 costal scutes (left and right), 5 vertebral scutes and 12 marginal scutes (left and right), 46 (11 .3%) individuals had a non standard scute count (Table 3).

DAMAGE. Of the 534 *E. m. krefftii*, 471 were checked for external damage upon capture. Of these 57 (12.1 %) were damaged; 43 turtles with carapace damage, 1 with eye damage, 3 with small holes in a marginal scute, 8 with a single limb missing and 2 with plastron damage. For the turtles with carapace damage 41 were scored for severity; 18 had damage to a single marginal scute, 12 had damage that crossed two scutes and 11 had damage that crossed three or more scutes. All damage to these turtles was restricted to the marginal scutes. There were no turtles with large compressed fractures or fractures across the costal or vertebral areas of the carapace or the bridge between the carapace and plastron.

Elseya albagula Thomson, Georges & Limpus, 2006

POPULATION CHARACTERISTICS. In this study 21 *E. albagula* occurred across the entire study area and were caught at five of the six sites. Most individuals were caught while snorkelling (Table 1). The size class distribution by sex (Fig. 4) of captured *E. albagula* indicates that there is a low frequency of the younger age classes — 17 were adult and 4 immature. Among the adults the sex ratio was nine females to eight males. Two of the four immature turtles were sexed by laparoscopic examination which identified one of each sex.

MORPHOLOGY. Adult females were larger than adult males in all aspects except tail measurements (Table 4). SCL of immature turtles ranged from 11.21cm to 28.32cm for the immature female. Although immature animals of both sexes had similar length tails for the same SCL, in adults the relationship between SCL and tail length was a reliable external measure of sex in adult turtles (Hamann et al., 2004). Of the 17 adults, the gender and maturity of two males and six females were based upon laparoscopic examination, or palpation for eggs. The remainder of classifications were based on tail and carapace measurements. There were no significant differences between SCL (female t test = 1.91, $P > 0.05$; male t test = 1.24, $P > 0.05$) or weight (female t test = 2.81, $P > 0.05$;

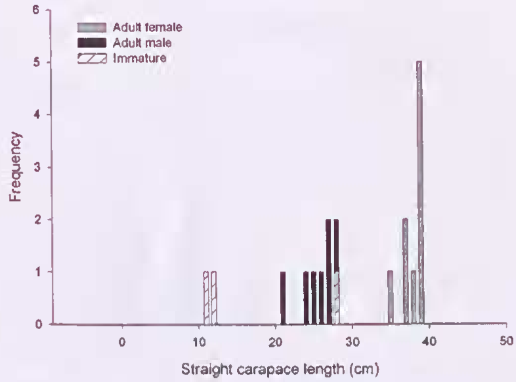

FIG. 4. Frequency distribution by size of *Elseya albagula* from the Paradise Dam area of the Burnett River.

male t test = 0.38, $P > 0.05$) between adult male and female *E. albagula* caught in this study compared with those caught downstream in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002).

REPRODUCTIVE BIOLOGY. Six of the nine adult female *E. albagula* caught had their reproductive status assessed by laparoscopy. All six of these females had small corpora albicantia on the ovary indicating that they had bred in a

TABLE 3. Scute counts for turtles caught in the Paradise Dam area of the Burnett River.

Scute	Scute count	Frequency			
		E. m. krefftii	*E. albagula*	*W. latisternum*	*C. expansa*
Nuchal	0	15	19	29	0
	1	393	0	5	4
Vertebral	4	1	0	0	0
	5	405	19	34	0
	6	2	0	0	3
	7	0	0	0	1
Costals	3/5	1	0	0	0
	4/4	399	19	34	4
	4/5	4	0	0	0
	5/4	1	0	0	0
	5/5	1	0	0	0
	4/6	1	0	0	0
	6/5	1	0	0	0
Marginals	11/13	1	0	0	0
	11/11	5	0	2	0
	11/12	1	0	0	0
	12/12	389	18	32	4
	12/13	5	0	0	0
	13/12	4	0	0	0
	13/13	3	1	0	0

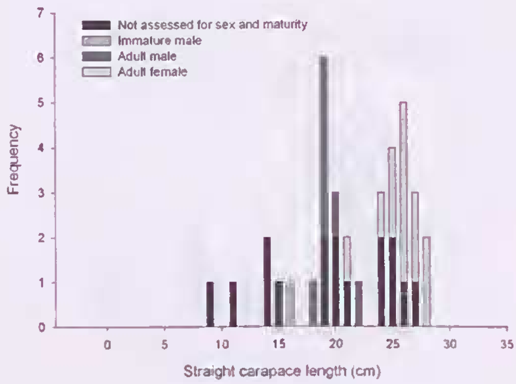

FIG. 5. Frequency distribution by size of *Wollumbinia latisternum* from the Paradise Dam area of the Burnett River.

previous season (five caught in October and one in November); all six of these turtles had one size class of large regressing corpora lutea on a vascular ovary, and small enlarged vascularised follicles. Each of these turtles had laid a single clutch of eggs within the previous few months, and were in early vitellogenesis for the next breeding season. Hence these six females were breeding in consecutive seasons. This data indicates a winter breeding season for female *E. albagula* in this area of the Burnett River Catchment.

Two adult male *E. albagula* had their maturity confirmed by laparoscopy: one caught in May 2003 was not assessed for breeding status, while the second, caught in August 2003 was in spermatogenesis.

Searches during May to September for evidence of turtle nesting, detected 22 clutches that had been recently destroyed by predators. Measurements of the length of eggshells were taken from six of the predated clutches identified 4 as *E. albagula* (mean shell length = 5.31cm ± 0.30 (range 4.86–5.75) and 2 nests as *C. expansa*. For 16 nests it was not possible to get diagnostic measurements from the egg shells. In most cases the predator(s) responsible could not be identified. However, broken *E. albagula* eggshells were found in goanna (*Varanus* species) faeces.

The *E. albagula* clutches were laid an average of 5.00 ± 4.08m (range 1.0–9.9m) from the water's edge, generally at the top of steep sloping banks (mean bank slope 54° ± 20°) and at a height of 3.20 ± 1.86m above the water level. Nesting habitat for *E. albagula* varied greatly. Soil type ranged from loose, light coloured sand, to sandy loam and compact dark soil. Three nests were found at a site underneath a closed *Casuarina* sp. canopy, and one nest was in a clear area on a sand bank. These nesting sites in the Goodnight Scrub National Park are within the area that will be flooded by the Paradise Dam. The 16 unconfirmed nests could have been from either of the winter nesting species, *E. albagula* or *C. expansa*. No decisive evidence of *E. albagula* nests was found within one km either side of the proposed site of the Paradise Dam wall.

In the area downstream of Gahans Road crossing a small sand island (~AMTD 163; 25.3941°S 151.6995°E) with an elevation between three and four metres above water level had several tracks presumably those of nesting females in May and June 2003. Despite being visited on three occasions no intact or predated clutches, and no nesting females were found to confirm whether the island is being used for nesting by *E. albagula* and/or *Chelodina expansa*. Tracks of terrestrial

TABLE 4. Measurements of adult *Elseya albagula* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	38.59	1.35	35.79–39.89	8	26.20	2.35	21.22–28.34	8
Straight carapace width (cm)	31.41	2.54	29.30–37.52	9	21.51	0.85	20.26–22.52	7
Plastron length (cm)	31.87	1.03	29.53–33.10	9	21.09	1.67	17.77–22.64	8
Plastron width (cm)	14.68	0.70	13.04–15.17	9	9.63	0.54	8.92–10.34	7
Head length (cm)	9.81	0.24	9.37–10.27	9	6.66	0.32	6.05–7.08	8
Head width (cm	6.60	0.41	5.60–7.07	9	4.55	0.12	4.36–4.70	7
Tail length from carapace (cm)	2.52	0.57	1.76–3.44	9	8.53	0.94	7.05–9.87	7
Tail length from plastron (cm)	9.85	0.91	8.72–11.20	9	13.61	1.00	11.90–14.96	7
Tail length from vent (cm)	6.77	0.57	5.86–7.72	9	6.94	0.79	5.89–8.00	7
Weight (kg)	7.39	0.78	6.25–8.90	9	2.25	0.59	1.04–2.85	8

predators such as foxes, cats, and goannas were not seen on the island during any visit. This island is within the area to be flooded by the Paradise Dam.

SCUTE COUNTS. Scute counts were made on 19 turtles. Most turtles had a scute count of zero nuchal scutes, 4 pairs of costal scutes, 5 vertebral scutes and 12 pairs of marginal scutes. One (5.3%) turtle had a non-standard scute count, with 13 marginal scutes on either side (Table 3).

DAMAGE. Nineteen of the 21 *E. albagula* caught were assessed for damage. Eighteen had no signs of external damage to their limbs, carapace, plastron or head; one had minor damage to a single marginal scute.

Wollumbinia latisternum (Gray 1867)

POPULATION CHARACTERISTICS. A total of 35 *W. latisternum* were caught over four of the six sites and one individual was killed by dam construction activities. Most individuals were caught by trapping (Table 1). Of the 36 individuals caught, 20 were examined by laparoscope for sex and maturity. Of these 20, 19 were adults (12 females and 7 males) and 1 was an immature male. An additional 11 individuals were of adult size but not assessed for maturity, and five immature turtles were too small for laparoscopic examination. The size class distribution by sex (Fig. 5) of captured *W. latisternum* indicates that there is a low frequency of individuals among the younger age classes.

MORPHOLOGY. Adult females were larger than adult males in all aspects except tail measurements (Table 5). The pubescent male was 16.23cm in SCL. The immature turtles ranged in SCL from 9.87cm to 15.13cm.

REPRODUCTIVE BIOLOGY. Ten of the 12 adult female *W. latisternum* had their reproductive status assessed by laparoscopy, dissection or palpation. In May each of the two females had small regressing corpora lutea on the ovarian stroma, and small, 2–3mm, developing vascularised follicles in the ovary. This indicates that they had recently completed a breeding season and were in vitellogenesis for the upcoming breeding season. Similarly, in June and August each of the five females had small regressing corpora lutea and an ovary containing large developing vascularised follicles, indicating that they had bred in the previous season and were in advanced vitellogenesis for the upcoming season. Hence all seven of the females assessed between May and August bred in two consecutive years. There were two adult females caught in November and one in December; these three females were carrying hard shelled eggs in the oviduct, had one size class of corpora lutea and no large developing ovarian follicles. Hence these three females had ovulated a single clutch for the season and did not have sufficient follicles for a second. Furthermore these data suggest that adult female *W. latisternum* have a vitellogenic period of at least five months prior to a summer nesting season. All ten females examined had corpora albicantia on the ovary indicating that they had bred in previous seasons.

Seven adult male *W. latisternum* had their reproductive status assessed by laparoscopy. A single turtle examined in May was not in spermatogenesis, while another single individual in August was. In November, of two males one was

TABLE 5. Measurements of adult *Wollumbinia latisternum* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	26.23	1.93	21.37–28.79	12	19.93	1.23	18.27–22.11	7
Straight carapace width (cm)	21.81	1.49	17.96–23.43	11	16.39	0.94	15.13–17.98	7
Plastron length (cm)	21.71	1.36	18.22–23.13	11	16.31	0.73	15.43–17.77	7
Plastron width (cm)	11.74	0.73	9.96–12.54	11	8.70	0.47	8.00–9.55	7
Head length (cm)	7.95	0.54	6.52–8.55	10	5.83	0.51	5.20–6.52	7
Head width (cm	5.72	0.41	4.71–6.16	10	3.99	0.34	3.56–4.50	7
Tail length from carapace (cm)	2.13	1.97	0.18–3.59	10	5.52	0.28	4.88–6.67	7
Tail length from plastron (cm)	6.54	1.25	4.12–7.96	10	8.54	0.23	8.17–9.53	7
Tail length from vent (cm)	4.04	1.09	1.25–5.07	10	3.58	0.34	3.17–4.15	7
Weight (kg)	2.54	0.49	1.37–3.29	11	0.94	0.18	0.74–1.31	7

in spermatogenesis and one was not. In January, of three males two were in spermatogenesis and one was not. The small sample size of adult male *W. latisternum* examined by laparoscopy precludes generalisations about the male reproductive cycle, other than to speculate that not all adult males breed in any one year.

SITE FIDELITY AND GROWTH. Only one *W. latisternum* was recaptured at an interval greater than six months; a pubescent male that was re-caught 370 days later in the same pool as its original capture. This turtle had grown 0.96cm over the intervening period. In addition, four of the unsexed immature turtles had recognisable hatchling scale and carapace growth layers. Assuming one growth layer equates to one year of growth (Hamann et al., 2004), these turtles were 11.5cm SCL at 2 years old, 9.87cm SCL at 4 years old, 14.65cm SCL at 5 years old, and 15.13cm SCL at nine years old.

SCUTE COUNTS. Scute counts were made on 34 individual *W. latisternum*. Most turtles had a scute count of: 0 nuchal scute, 4 pairs of costal scutes, 5 vertebral scutes and 12 pairs of marginal scutes; however seven (23.3%) had a non-standard scute count. The seven turtles with abnormal scute counts comprised five turtles with one nuchal scute and two turtles with 11 marginal scutes on one side (Table 3).

DAMAGE. Thirty of the 33 *W. latisternum* caught were assessed for damage. 28 turtles had no signs of external damage to the carapace, plastron, limbs or head. Two turtles had minor damage to the carapace and plastron respectively.

Chelodina expansa (Gray 1857)

Four *C. expansa* were caught within the study area. Two were adult males (SCLs of 25.84 and 25.04cm), one was an unsexed immature (SCL of 26.34cm), and one was classed as a male based on tail length but was not assessed for maturity. None had signs of external damage but one had an abnormal scute count (Table 3). During searches for nesting sites between July and September 2003 and 2004, two *C. expansa* nests were encountered at the Paradise Dam site. In both cases only scattered shells were found in an area with tracks and scats of goannas.

DISCUSSION

Four species of freshwater turtle (*Emydura macquarii krefftii*, *Chelodina expansa*, *Wollumbinia latisternum* and *Elseya albagula*) were caught in the area of the Burnett River that will be flooded by the Paradise Dam. *E. m. krefftii* was the most common with the other species being less frequently encountered. This pattern of species abundance is similar to that recorded in other areas of the Burnett River catchment (Tucker, 1999; Limpus et al., 2002).

While adult male *E. m. krefftii* caught in this section of the river are larger in carapace length and heavier than those caught downstream in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002), adult females showed no significant difference. In addition, AS_{50} values for both sexes are similar between the two studies and the assessment of reproductive patterns show late spring–summer nesting and annual breeding occur in both locations. These reproductive characteristics are similar to those reported by Georges (1983) and Tucker (1999) for the same species in other locations in Queensland. Data are not available for either site that would improve analysis of reproductive patterns with respect to clutch size and within season clutch frequency.

Similarly, the morphological and reproductive data we report for adult *E. albagula* are similar to those reported on for the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002) and for the broader Burnett River Catchment (Hamann et al., 2004). Additionally, comparisons of reproductive data from throughout the catchment indicate that *E. albagula* breeds at similar times of the year (winter) and most females are breeding annually.

Frequency distributions for three of the four species caught are positively skewed towards adults, indicating a shortage of animals in the smaller size (~ equals younger age) classes. Indeed for *E. m. krefftii*, *W. latisternum* and *E. albagula* only 23%, 18% and 19% respectively of the turtles caught, were classed as immature. These size frequencies for each species are similar to those reported pre-construction in the Ned Churchward Weir (formerly Walla Weir) area (Limpus et al., 2002) and for the broader Burnett River Catchment (Tucker, 1999; Hamann et al., 2004). It is unlikely that these frequencies result from low reproductive output from females or are an artefact of capture methods. Low reproductive output is unlikely because in our study and previous studies within the catchment almost all adult females caught in each species have been found to breed annually. It is not likely to result from size related bias in catch methods because; the same methods have been used, and in many cases the same personnel, to successfully catch turtles of all size ranges in other locations (e.g. Albert River, SE Qld, and Waruma Dam, Burnett River (QPWS unpublished data)) and at the three sites where most effort was employed a variety of sampling methods were used at multiple times of the year across multiple microhabitats.

In addition, in this study we caught low numbers of pubescent immature turtles and four adults breeding for the first time for *E. m. krefftii*, and none for *W. latisternum* and *E. albagula*. Although, we have small sample sizes for two of these species, when our data is compared and combined with data from previous studies in the Burnett River a similar trend is found (Tucker, 1999; Limpus et al., 2002; Hamann et al., 2004). Hence, in the section of river we report on here, and in the broader Burnett River Catchment each of these three species have low numbers of individuals in immature size classes and low recruitment to adult status compared to the numbers of adult turtles that have bred over multiple seasons.

Freshwater turtle populations that are not functioning well are characterised by positively or negatively skewed size or age class frequency classes (Congdon et al., 1993; Spinks et al., 2003). Indeed the population structure of turtles that we found within this study is similar to the structure in populations of freshwater turtles that have been impacted by widespread and long running egg mortality elsewhere in Australia (Thompson, 1983; Flakus, 2002). Our data, and those of previous studies, indicate that the populations of freshwater turtles within both the area to be flooded by the Paradise Dam and in the broader Burnett River Catchment have low survival of eggs or hatchlings. Moreover, because there is a bias towards adult sized turtles in the populations we suggest these aspects have occurred over a long time frame within the catchment, and have ultimately led to a population bias towards adult sized turtles.

Despite extensive sampling effort over 500 metres either side of the site of the dam wall, that included the draining of an entire pool of water at the wall site, we only found a single *E. albagula* individual. Moreover we only caught one turtle at the study site below the wall site (Campbell's property). Hence in this area of the Burnett River, *E. albagula* occurs at very low densities and our data will provide a useful baseline from which to compare future densities at this site following the construction of the dam. This is interesting because in the years following the construction of the Ned Churchward Weir, surveys have revealed that large numbers of *E. albagula* reside in the pools immediately downstream of the weir wall (Hamann et al., 2004). It is not possible to estimate whether these aggregations occurred pre-construction because the Limpus et al. (2002) study did not sample the area downstream of where the wall was constructed.

Since the studies by Limpus et al. (2002) and Tucker (1999) an additional threat has been documented to freshwater turtles within the Burnett River Catchment, namely a higher incidence of damage to individuals residing in and around plunge pools of impoundments Hamann et al. (2004) reports that damage to turtles occurs in varying degrees from small single scute fractures to lethal multiple scute fractures that expose internal organs, and does not seem to be species or size class specific. In particular turtles residing in pools on the downstream side of impoundment walls had higher incidence of damage than those turtles inhabiting free flowing sections of river. Our study of 520 turtles occurring immediately downstream of the impoundment wall recorded only minor damage to marginal scutes of 60 individuals. This incidence is substantially lower than Hamann et al. (2004) report for turtles residing downstream of Ned Churchward and Bucca Weirs, and similar to those figures reported for other un-impounded sections of river such as Barambah Creek and Electra. Therefore, our data will serve as a useful baseline figure from which to compare the future impact of the Paradise Dam on the health and condition of the turtles of the system.

ACKNOWLEDGEMENTS

This project was conducted by the Queensland Parks and Wildlife Service as part of the Burnett Program of Actions (*Elseya* sp. [Burnett River] project) funded by the Queensland Department of State Development and Innovation. We would like to thank G. Campbell and M. Matheson for allowing us to access the river through their properties and the numerous volunteers that helped in various aspects of the project. Burnett Water Pty. Ltd. provided access to the Paradise

Dam site during the construction phase. This assistance is gratefully acknowledged. Animal ethics approval for this study was granted to the Queensland Turtle Conservation Project by permit SAREEC010.

LITERATURE CITED

BENJAMIN, C. 1995. The Burnett Catchment. (Unpub. report to Queensland Department of Primary Industries: Brisbane)

BODIE, J.R. 2001. Stream and riparian management for freshwater turtles. Journal of Environmental Management 62: 443–455.

CONGDON, J.D., DUNHAM, A.E. & VAN, L.S.R.C. 1993. Delayed sexual maturity and demographics of Blanding's turtle (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology 7: 826–833.

FLAKUS, S. 2002. The ecology of the Mary River turtle, *Elusor macrurus*. Masters thesis, Department of Zoology and Entomology, The University of Queensland, Brisbane.

FONNESBECK, C.J. & KENNETH DODD, C. 2003. Estimation of flattened musk turtle (*Sternotherus depressus*) survival, recapture, and recovery rate during and after a disease outbreak. Journal of Herpetology 37: 602–607.

GEORGES, A. 1983. Reproduction of the Australian freshwater turtle *Emydura krefftii* (Chelonia: Chelidae). Journal of Zoology, London 201: 331–350.

GRAY J.E. 1857. Description of a new species of *Chelodina* from Australia. Proceedings of the Zoological Society of London 1856: 369–371.

1867. Description of a new Australian tortoise (*Elseya latisternum*). Annals and Magazine of Natural History (3) 20: 43–45.

1871. Notes on Australian freshwater tortoises. Annals and Magazine of Natural History (4)8: 366.

GIBBONS, J.W., LOVICH, J.E., TUCKER, A.D., FITZSIMMONS, N. & GREENE, J.L. 2001. Demographic and ecological factors affecting conservation and management of the diamondback terrapin (*Malaclemys terrapin*) in South Carolina. Chelonian Conservation and Biology 4: 66–74.

HAMANN, M., SCHÄUBLE, C.S., LIMPUS, D.J., EMERICK, S.P. & LIMPUS, C.J. 2004. The Burnett River snapping turtle, *Elseya* sp. [Burnett River] in the Burnett River Catchment, Queensland, Australia: Biological Report, 2004. (Unpublished report to Queensland Environmental Protection Agency, Brisbane).

KRAUSE, A. & OLSON, M. 2002. The basics of S and S-Plus (4th Edition), (Springer-Verlag, New York).

LIMPUS, C.J. & LIMPUS, D.J. 2003. The biology of the loggerhead turtle, *Caretta caretta*, in southwest Pacific Ocean foraging areas. Pp. 93–113, *in*, Witherington, B. & Bolten, A. (eds) Biology and Conservation of Loggerhead Turtles. (Smithsonian Institution Press: Washington, D. C.).

LIMPUS, C., LIMPUS, D. & HAMANN, M. 2002. Freshwater turtle populations in the area to be flooded by the Walla Weir, Burnett River, Queensland: Baseline study. Memoirs of the Queensland Museum 48: 155–168.

PRITCHARD, P.C.H. & TREBBAU, P. 1984. The Turtles of Venezuela. (Society for the Study of Amphibians and Reptiles: Athens, USA).

ROMERO, L.M. & WIKELSKI, M. 2001. Corticosterone levels predict survival probabilities of Galapagos marine iguanas during El Nino events. Proceedings of the National Academy of Sciences of the United States of America. 98: 7366–7370.

SPINKS, P.Q., PAULY, G.B., CRAYON, J.J. & SHAFFER, H. 2003. Survival of the western pond turtle (*Emys marmorata*) in an urban California environment. Biological Conservation 113: 257–267.

THOMPSON, M.B. 1983. Populations of the Murray River tortoise, *Emydura* (Chelodina): The effect of egg predation by the red fox, *Vulpes vulpes*. Australian Wildlife Research 10: 363–371.

THOMSON, S., GEORGES, A. & LIMPUS, C.J. 2006. A new species of freshwater turtle in the genus *Elseya* (Testudines: Chelidae) from central coastal Queensland, Australia. Chelonian Conservation Biology 5: 74-86.

TUCKER, A.D. 1999. Cumulative Effects of Dams and Weirs on Freshwater Turtles: Fitzroy, Burnett and Mary Catchments. Unpublished report to Queensland Parks and Wildlife Service.

VAN MANEN, N. 1999. State of the Rivers: Burnett River and Major Tributaries; An Ecological and Physical Assessment of the Condition of Streams in the Burnett, Kolan and Burrum River Catchments. (Unpublished report to the Department of Natural Resources, Natural Sciences Precinct: Brisbane).